NANOSECOND STRUCTURAL VISUALIZATION OF POLARIZATION SWITCHING IN FERROELECTRICS

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Although the switching of ferroelectric polarization has been investigated for decades there has been no direct nanosecond-scale visualization of the switching process in crystalline thin film ferroelectrics. The domain wall motion associated with polarization switching in ferroelectric thin films is fundamentally important and presents challenges for both experiments and theoretical modeling. We will discuss synchrotron-based probes that have space and time resolutions that make it possible to study the dynamics of strain and ferroelectric polarization and the relationship between them in a number of ferroelectric materials and devices.

We have visualized the switching process in a $Pb(Zr,Ti)O_3$ capacitor at micron length scales with subnanosecond time resolution using time-resolved x-ray microdiffraction. The structural signatures accompanying polarization switching include a reversal in the sign of the piezoelectric coefficient and a change in the intensity of x-ray reflections due to non-resonant anomalous scattering. The propagation of polarization domain walls is highly reproducible from cycle-to-cycle of the electric field. Two dimensional maps of the polarization reversal allow direct measurements of the polarization domain wall velocities inside an operating device. Effective domain wall velocities in our devices are on the order of 40 m s^{-1}, consistent with an extrapolation of low-field results obtained with other microscopic probes. We will also discuss the use of similar techniques to study polarization switching in $BiFeO_3$ thin films.